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A METHOD FOR DESIGNING INLET DISTORTION SCREENS FOR AIRCRAFT GA--ETC(U)
MAY 82 R E ANDERSON
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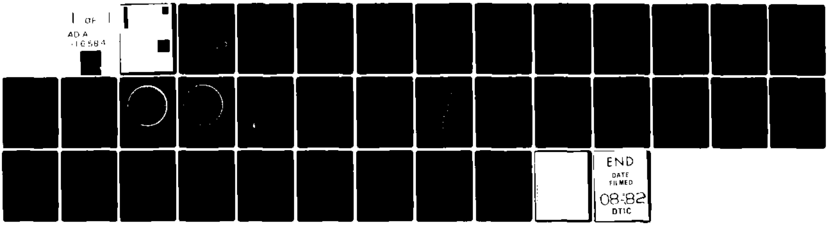

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The design of inlet distortion screens used for testing aircraft gas turbine engines can be facilitated by using an interactive computer program. This report describes a computer program which has been developed by the Naval Air Propulsion Center to aid in the screen design process. The computer program can be used to establish the initial screen design and to develop modifications after the screen is tested.

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NAPC-PE-66 MAY 1982

A METHOD FOR DESIGNING INLET DISTORTION SCREENS FOR AIRCRAFT GAS TURBINE ENGINE TESTS USING AN INTERACTIVE COMPUTER PROGRAM

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INTRODUCTION

Distortion of the total pressure at the inlet of an aircraft gas turbine engine continues to be a significant factor affecting the stability and performance of engines in service and a major consideration for new engine designs. Increasing power-to-weight ratios enables newer aircraft to perform maneuvers that were not possible in previous generations with older aircraft. The airframe manufacturer must design an inlet that will perform well over a wide range of conditions, and the engine manufacturer must design a propulsion system that functions efficiently throughout the same set of conditions.

Information regarding distortion levels/patterns is usually derived from wind tunnel tests of scale models before an aircraft flight test is performed. During the development of an aircraft/propulsion system, a portion of the aircraft flight test program is dedicated to defining engine inlet distortion patterns and uncovering distortion problems. Data derived from these flight tests can then be used to define conditions for further ground tests.

Installation of a screen specially designed to produce the particular distortion pattern in an inlet duct just in front of a test engine has been a traditional way of investigating engine stability performance. Screens have severe limitations, however, and other techniques have been investigated (with some success) to displace them. Until these techniques become more generally accepted, the capability to design and fabricate distortion screens will continue to be required to support ground facility tests.

The basic concept for designing screens, based upon dividing the sections of screen into discrete flow areas, has been in use for some time and is described in reference 1. Unfortunately, the methods used to develop an acceptable inlet distortion screen require extensive analysis and "cut-and-try" techniques that result in a time-consuming process.

This report describes a computer program recently developed by the Naval Air Propulsion Center (NAPC) to aid in the screen design process. Although the designer must still make judgemental decisions during the screen design process, this program and an interactive computer terminal will permit the designer to assess more variables and determine the effects in a shorter time period than previously possible. Development of this computer program was accomplished as a phase of the program authorized by reference 2.

CONCLUSION

1. The computer program described in this report and a computer interactive terminal can be used effectively to design an engine inlet distortion screen with improved quality and in a shorter time period than previously possible.

RECOMMENDATION

1. It is recommended that the computer program described herein and an interactive terminal be used by the distortion screen designer to assist in the development of engine inlet distortion screens.

DISCUSSION

A. General

The following paragraphs will present the steps and judgements required by a screen designer to develop an inlet distortion screen that simulates a particular aircraft inlet pressure distortion pattern for gas turbine aircraft engine tests in a ground facility. The initial screen design process, verification test methods and redesign techniques will be described. Although the screen design methodology is rather "classical" in nature, a computer program developed by NAPC will be introduced to show how the quality and timeliness of the design process can be improved by use of the program and an interactive computer terminal.

B. NAPC Screen Design Computer Program

Appendix A describes the capabilities of the screen design computer program, including the menus provided on a terminal display, the parameters required to be input to the program and the output displays. The program prepared in the FORTRAN programming language was written for the in-house PDP 11/70 computer.

C. Initial Design and Test of Screen

1. Pressure Contour Selection

To begin the process of designing a screen, total pressure data defining the desired/required distortion condition is run in the NAPC graphic computer program to produce a plot of isobars. The data is usually derived from a 40-point arrangement as described later. The visual display produced by the NAPC computer program can show as many as 10 different constant pressure lines. For example, in the figure 1a display, data for a particular desired condition has been plotted for nine isobars; the same data is plotted in figure 1b for four isobars. Symbols on the lines represent the various pressure levels (in psi) listed to the far left of the plot. The numbers under the "area" column represent the area in square inches between adjacent isobars. The pressure in each area is assumed to be the average of the two adjacent isobars. Each area is considered to be, or act as, an individual stream tube. Since the fabrication of a distortion screen involves the difficult task of cutting pieces of screen of various meshes (blockages) for each area defined by the computer program, it is most practical to minimize (within reason) the number of areas defined.

It should be emphasized here that the NAPC computer program and an interactive computer terminal represent powerful tools for providing area calculations. Earlier screen design work was often accomplished using a planimeter to obtain the areas of the irregularly shaped sections. Although a computer might have been available for some calculations, the difficulty in implementing an area change was so cumbersome that the original areas often were maintained through the whole screen development process.

After the area for each section, or stream tube, is established (as in figure 1a or 1b) and the total pressure associated with each section is known, a single static pressure common to all sections must be developed. Again, the NAPC screen design computer program plays an important part in the development of the common static pressure. The computer begins this phase of the process by arbitrarily choosing a static pressure equal to the lowest total pressure desired at the engine inlet and assumes that this static pressure is common across the face of the engine inlet. The computer program then calculates the airflow for each section, using the average total pressure for the particular section, the arbitrarily chosen static pressure and the average total temperature for the desired condition. The individual calculated airflows for the various sections, or stream tubes, are summed by the computer to indicate the total airflow. This total airflow must meet the requirements of the engine for the desired test condition. If it does not, then a new static pressure is chosen by the computer and the airflow calculation process is repeated. The iteration process continues until a common static pressure is derived which yields section airflows that, when totalled, meet engine requirements for a desired condition.

The initial assumption that a common static pressure exists at the engine inlet plane is important to this phase of the screen design process. This assumption is consistent with one dimensional flow theory, which assumes that every point lying in a plane perpendicular to the flow stream is at the same static pressure.

2. Porosity Selection

After the static pressure and individual stream airflows have been determined, the screen porosity for each section must be determined. Porosity, as used in screen work, is defined as the amount of open flow area divided by the total area for a particular screen, or section. It can be calculated if the size of the wire used in making the screen and the spacing of the wire are known. Screen manufacturers catalog screens of a variety of porosities.

The engine inlet distortion pattern will eventually be produced by a screen unit composed of pieces/sections of screen, each with a different porosity, wired to a base grate made of heavy wire to withstand the buffeting of the airflow. To initiate the process of defining the porosities of the various section screens, the base grate must be

selected. A base grate with a porosity of approximately 0.90 represents a good starting point. (In special cases, the screen designer may elect to choose a base grate of lower porosity as a starting point to get a better match with available catalogued screen sizes.) The base grate and porosity are used to describe the screen for the section with the highest desired average total pressure defined earlier. Using the porosity of the section and the earlier calculated open area, a new open area can be derived. The next step in the process is to calculate the upstream pressure based on the selected base grate. The upstream pressure is obtained by substituting the following in the basic airflow equation: (1) the stream airflow for the section, (2) the common static pressure defined earlier, (3) the desired total temperature and (4) the new open area to solve for the upstream total pressure. This calculated upstream total pressure is then assumed to be the same for all screen sections.

Using the upstream total pressure, the common static pressure previously established and the airflow for each particular section, a new open flow area can be calculated for each section. This new open flow area divided by the original area of the particular section establishes the porosity of that section.

The NAPC screen design computer program performs all of the calculations required in the porosity selection process. The designer merely designates the base grate porosity and the computer calculates the porosities of each section.

From the screen porosities determined for the various flow streams, screen segments can be selected based on available literature from screen manufacturers. If the required porosities calculated by the computer do not match well with the porosities of screens available from manufacturers, a rerun of the program with a different base grate may result in a better match. After definition of the porosities of the various sections and selection of the wire mesh for each section, the inlet distortion screen fabricator will have sufficient information to make the initial screen. Figure 2 shows a typical fabricated inlet distortion screen.

3. Testing the Initial Design

To verify screen performance, the screen is installed in a test chamber along with suitable instrumentation and in a configuration duplicating the engine inlet. Since operation of the test engine for screen calibration purposes is extremely expensive, screens are normally calibrated/checked without the engine. It has been observed from previous screen calibrations that operation of the engine behind a screen has a minor effect on the distortion pattern produced by the screen. This minor effect is more than cancelled by the impreciseness/assumptions made to design the screen.

A typical screen calibration test installation at NAPC is shown in figure 3. This screen test, which preceded a General Electric F404-GE-400 engine development test in an altitude chamber, utilized a dummy F404 engine inlet and the engine bullet nose to more realistically duplicate the inlet. Airflow across the screen was regulated by controlling the upstream and downstream pressure to match the required test point.

Placement of the screen is important in the calibration process. The screen must be installed at an optimum distance in front of the engine. If the screen is placed too far upstream, the distortion pattern will tend to dissipate, and strong levels of distortion may not be produced. Experience has shown that a distance of approximately one-half diameter in front of the engine inlet is satisfactory. This distance leaves room for the installation of the pressure rakes.

The most commonly accepted arrangement used to measure the effect of the screen is an array of 40 probes. Eight rakes are spaced circumferentially at 45° intervals, and each has five pickups. These pickups are located at the centroids of five equal areas (see figure 4). Some test programs have employed 48 pickups, with six probes on each of eight rakes. It is important to have sufficient probes to accurately assess the pressures at the engine inlet plane, but not so many that rake blockage will seriously affect engine performance.

The rakes are usually installed in a plane just ahead of the engine bullet nose. One manufacturer, however, built probes into the inlet guide vanes of one of his development engines to eliminate the undesirable effects of rake blockage. Fabrication and installation of the probes was undoubtedly a sizeable achievement and limited flexibility with the special instrumentation to the one engine only.

D. Comparison of Test Results Against Desired Results

1. Three Comparison Methods

It is important to establish ground rules early in the screen design process on the pressure measuring techniques and the degree to which the desired pattern must be duplicated. Fine tuning the design through repeated design changes is costly and time consuming.

After the data has been obtained from the calibration run, it can be entered into the computer and the results compared with the original desired data. This comparison can be accomplished by any of at least three methods:

a. Visual comparison of contour plots

b. Comparison of distortion indices

c. Comparison of ring plots.

2. Visual Comparison of Contour Plots

The first method is a simple comparison of the isobar plot of the test data to an isobar plot of the desired pattern. Although this method is subjective, it is a simple, logical approach to comparing the patterns.

3. Distortion Indices

The comparison of test versus desired data based on the calculation of a single number which can be equated to the amount of distortion is another comparison approach. A "distortion index" is usually used for evaluating such a level of distortion. Several distortion index calculation methods have been developed by industry. Most of these methods relate measured values and the size of a low pressure section to the overall average pressure.

No universal distortion index has yet been agreed upon, but a Society of Automotive Engineers Aerospace Recommended Practice (ARP) is expected to be published in the near future. If this ARP gains acceptance throughout industry it will facilitate comparison of distortion levels between different systems.

Past engine programs have usually used the distortion index adopted by the engine manufacturer whose engine is to be tested with the screen. Most engine manufacturers have adopted a particular inlet distortion index method and applied it to all of the engines developed within their company. This has permitted some continuity within the company for screen design and engine design purposes. Obviously, as long as the screen designer uses the same distortion index calculation method for both the test data and desired data, he can make a valid comparison.

4. Ring Plots

A third comparison technique is to plot the values of pressure at the same radial location, progressing around the inlet circumferentially. For the 40-pressure array, this results in five ring plots with eight points on each. If the desired design data is plotted for a particular ring and the test run data is overlaid, the differences can be simply observed. Figure 5 is a sample computer ring plot, comparing test data to desired values.

E. Design Revisions

1. Some Approaches to Screen Design Revisions

Initial screen designs rarely meet the total distortion requirements at the engine inlet. Often a desired level of pressure is not achieved in a particular engine inlet area, and the designer

must change either the porosity or shape of a screen section and modify the original screen. The assumption of one dimensional flow (and a constant static pressure level across the screen) is one source of error since, in reality, this assumption may not be entirely valid. As mentioned earlier, the interaction of an operating engine behind a screen and the particular screen design can also sometimes produce results at the engine inlet which differ from the prediction. Although the difference is generally not large, it may be significant. Figure 6 shows the result of placing a screen blockage of 180° in front of an engine to attempt to produce the classic pattern shown at the top. In this case, the effects of the boundary layer and engine bullet nose produced the pattern in the lower plot. Swirl can also be observed.

If a few specific probes indicate pressure levels significantly different than the desired values, the desired values for these probes can be manipulated in the computer data array to develop an isobar plot of the test data. The differences between the plots of desired and test isobars can often offer clues to modifications to the screen which might provide more positive results.

Some judgement on the part of the designer is still required. Obviously, if the computer prediction was totally accurate, the first design would have resulted in success. Since the NAPC computer program plots the isobars by a spline curve fit routine, the prediction should at least be superior to a linear interpolation between adjacent probes.

A close familiarity with the distortion index used to measure the distortion achieved can lead to an approach where a few pressure readings are identified as those having the major impact on the index calculation. Upon identification of these critical pressure points, an experienced screen designer can often make a minimal number of pressure boundary/screen design changes to achieve the desired results.

If the desired pattern is generally matched, but a particular pressure is not achieved in a certain area, the NAPC computer program permits the designer to revise the area and recalculate porosity. With the new porosity and area, the screen fabricator can make appropriate revisions to the original screen. The modified screen can then be retested. If the desired pressures/patterns are not achieved at this point, the designer will have enough information to understand the effect of a porosity change to the questionable area, and a final design can be developed.

2. NAPC Computer Program Constraints

The NAPC inlet distortion screen design computer program tends to produce screen patterns which are not quite as severe as those desired. One necessary assumption that contributes to this effect is that the total pressure upstream of the screen is constant across the duct plane. The designer may have to compensate for this program anomaly by inserting slightly different pressures into the program, checking the pattern produced and continuing this process until the desired pattern is reached.

The NAPC computer program does not lead the designer directly to a solution (i.e., it does not converge to a solution). The designer must keep track of the changes he enters into the program and the effect of the changes on the resultant screen configuration. Such an approach may be feasible, but a much more sophisticated computer program would be required to achieve this capability.

A third limitation of the NAPC computer program is that it cannot directly move the contour line of an isobar plot; however, numerical values can be simply substituted in the pressure array to shift contours.

F. Alternate Design Method

An alternate method of screen design involves the use of geometric shapes. For an array of 40 probes in a circular duct, a geometric pattern can be defined. Eight pie-shaped sections, each covering a 45° arc, and five concentric circles of equal areas divide the flow area into 40 equal parts (see figure 7). The pressure reading from any one probe will define the total pressure for the associated area.

The NAPC computer program would not be utilized initially if this approach is selected, as each area is defined geometrically. The various smaller areas would then be grouped by common pressures to produce up to 10 larger areas. This method may not lead to as good a match with the desired pattern as the approach described in this report, but the fabrication of screen sections is simplified. The porosity of the various sections can be derived from the computer program after entering the large calculated areas.

The viscous mixing of the airstream after leaving the screen, and the movement of the high pressure streams with the low pressure streams, will tend to alter the sharp geometric patterns as described earlier.

If a change is decided upon after blowing air across the screen, it is relatively easy to substitute a redefined area with a different porosity.

Originally dividing the flow area into the same number of sections as there are probes is not mandatory. This method is particularly effective, however, where the desired pattern has a symmetrical shape. For example, a screen was designed recently for a single engine airplane with a bifurcated inlet. In addition to the typical boundary layer area, a blockage occurred where the vertical splitter plate was mounted in front of the engine. By considering the blockage inherent in the configuration, the development of a screen by the geometric method proved successful. Excellent agreement was obtained with data taken from probes mounted at the engine inlet in the aircraft.

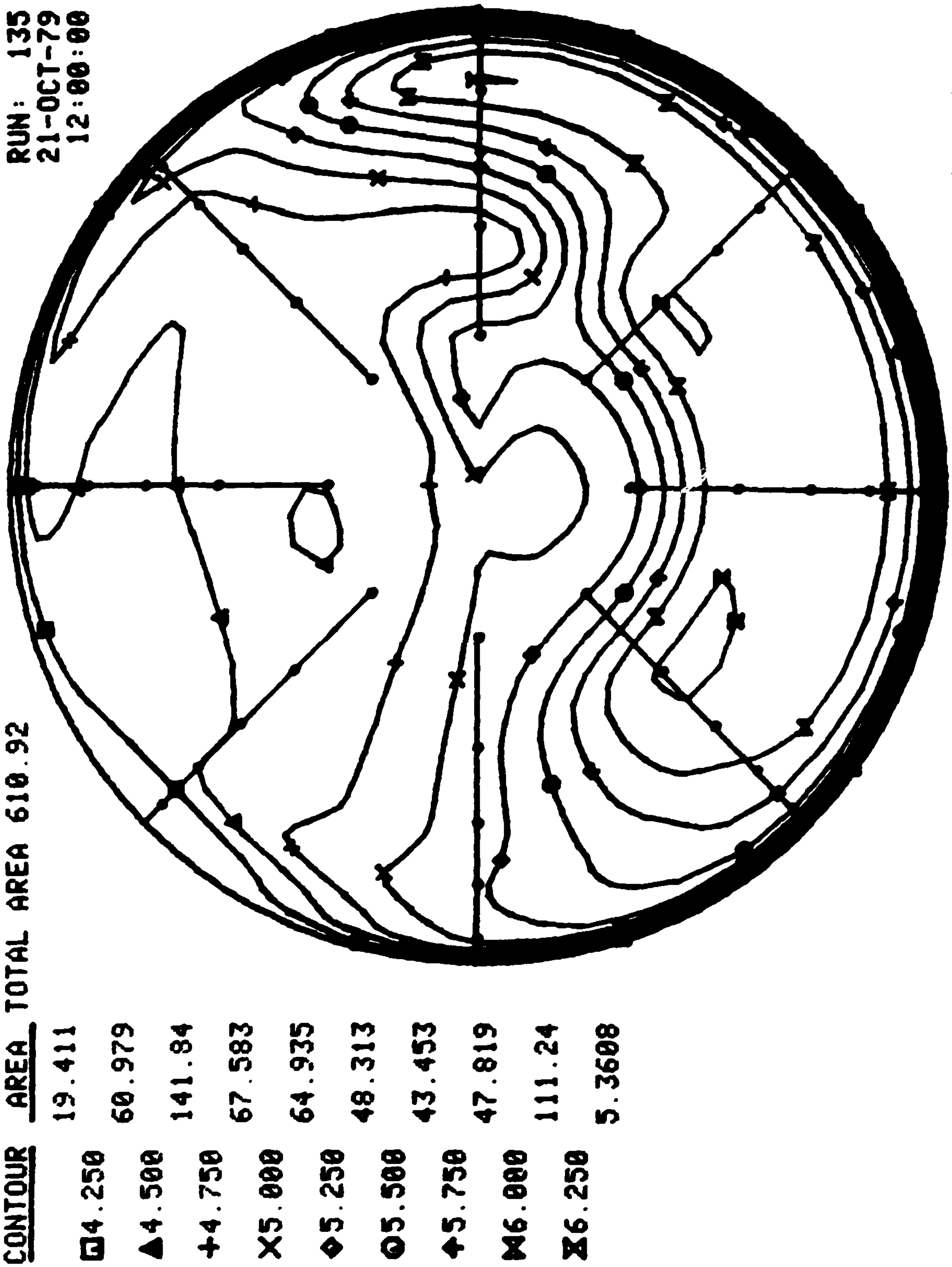


FIGURE 1a. - CONTOUR PLOT - NINE ISOBARS

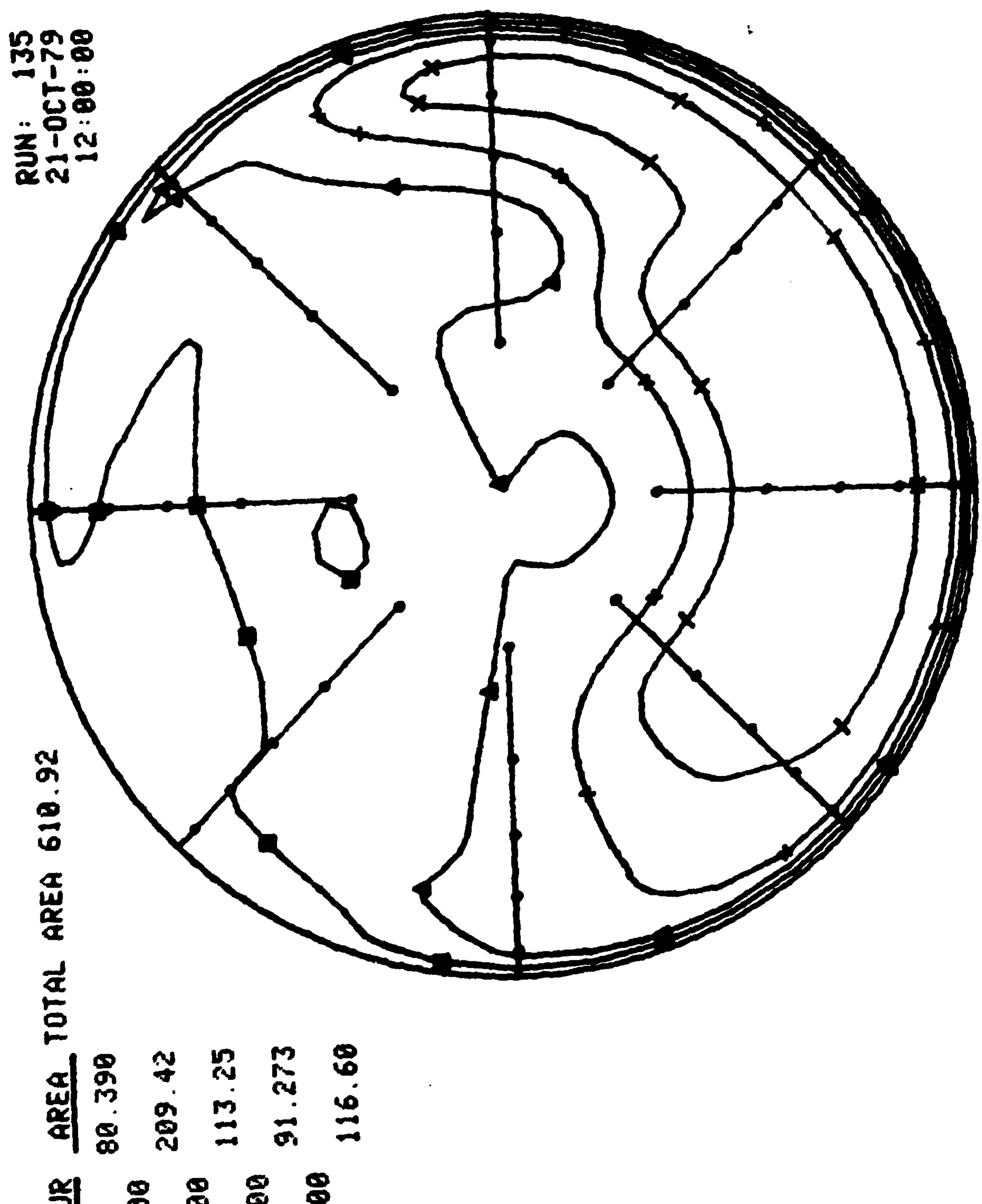


FIGURE 1b. - CONTOUR PLOT - FOUR ISOBARS

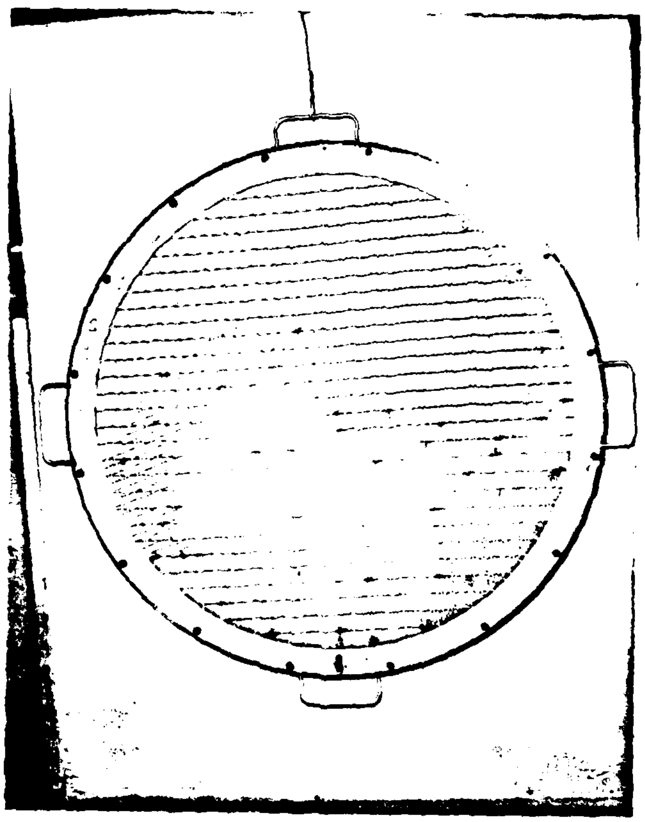


FIGURE 2. - TYPICAL FABRICATED INLET DISTORTION SCREEN

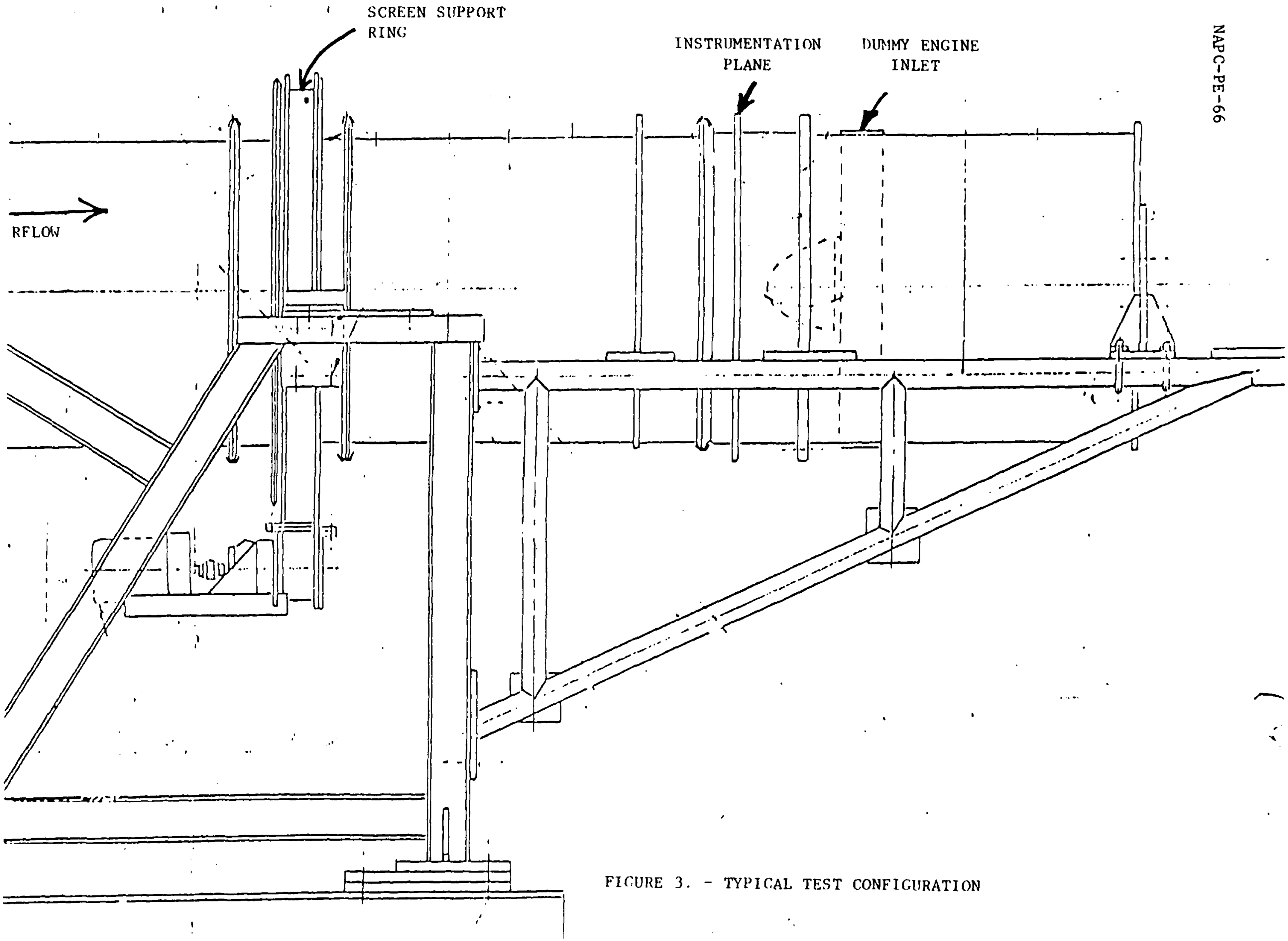


FIGURE 3. - TYPICAL TEST CONFIGURATION

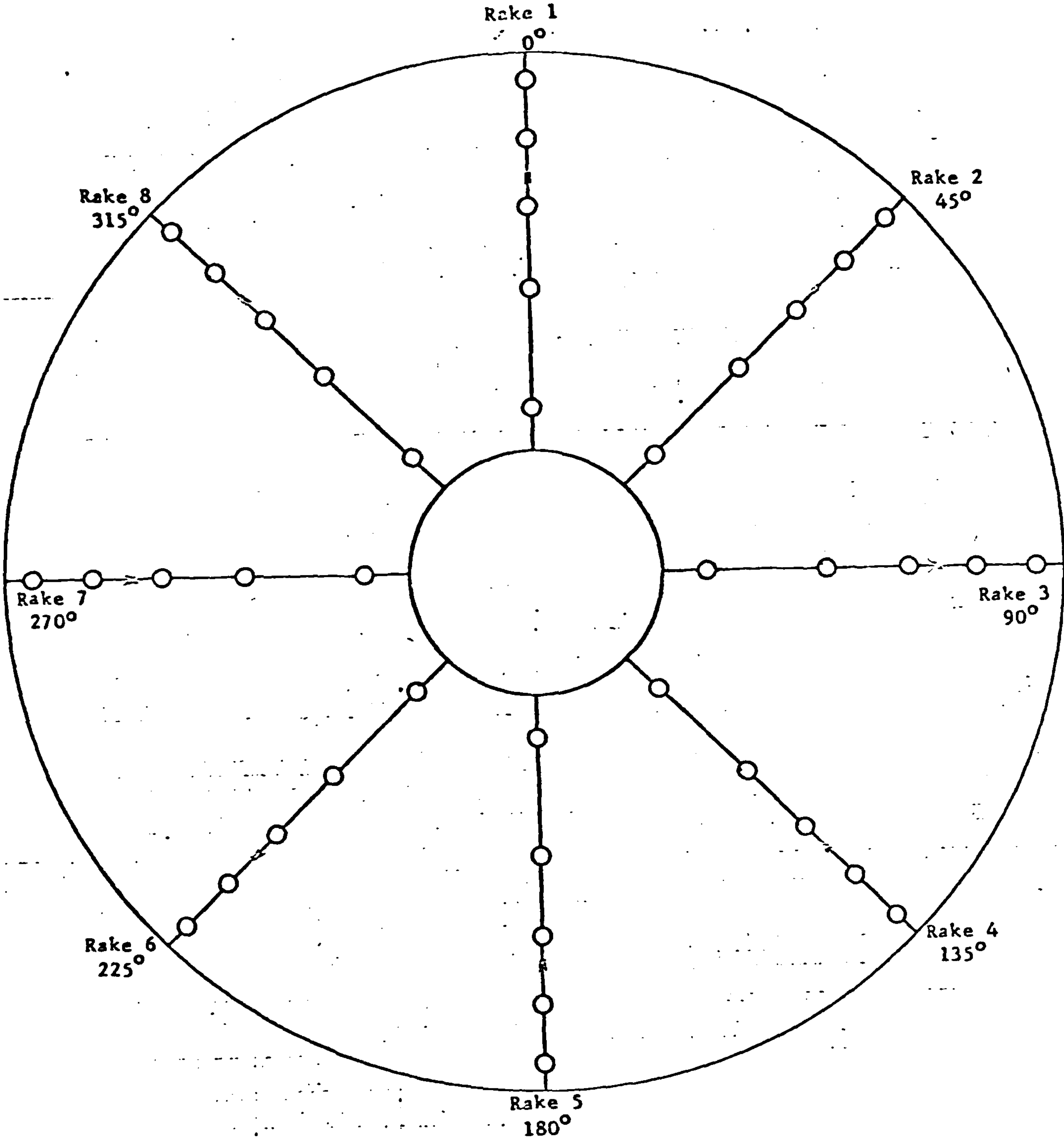


FIGURE 4. - PRESSURE RAKE GEOMETRY

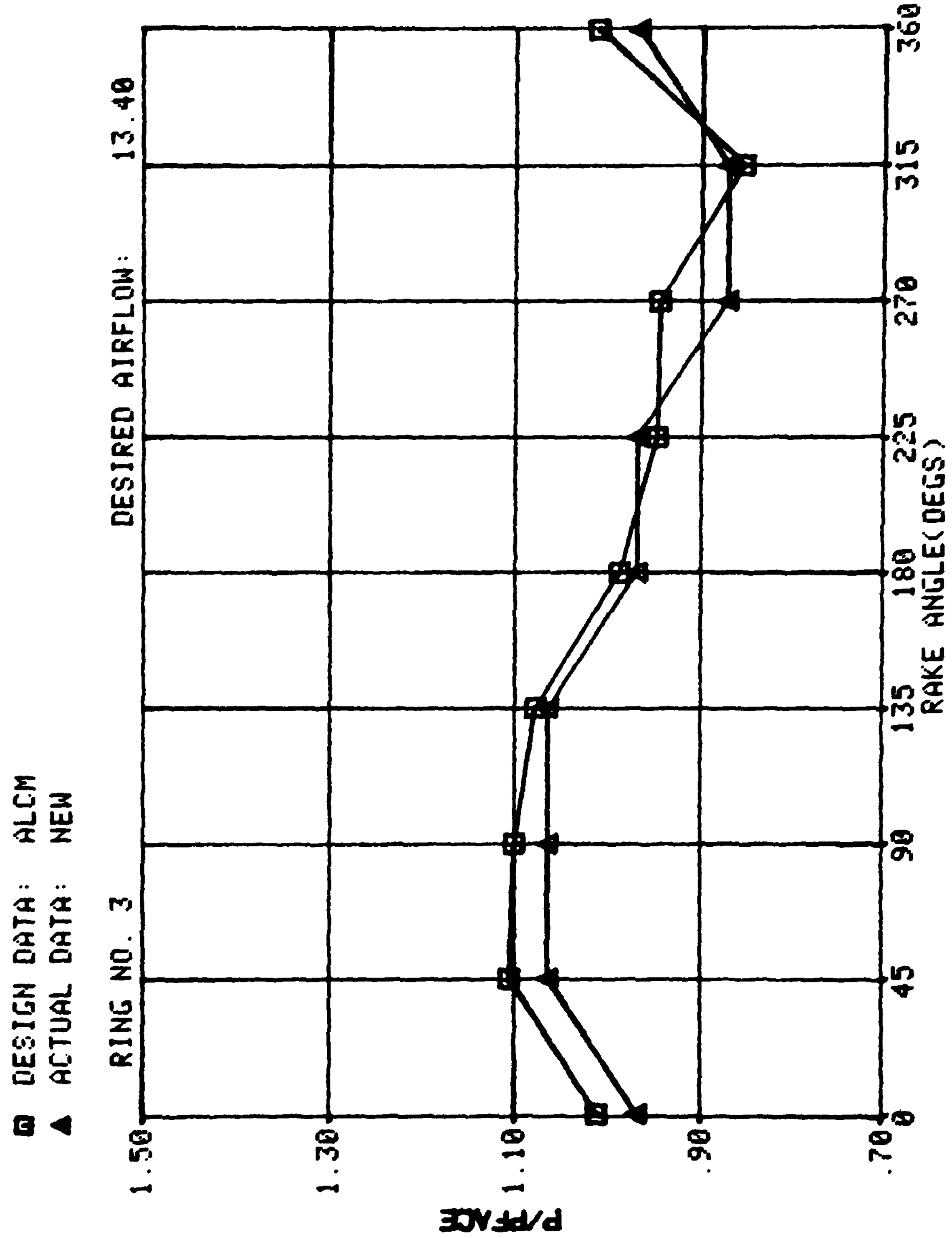
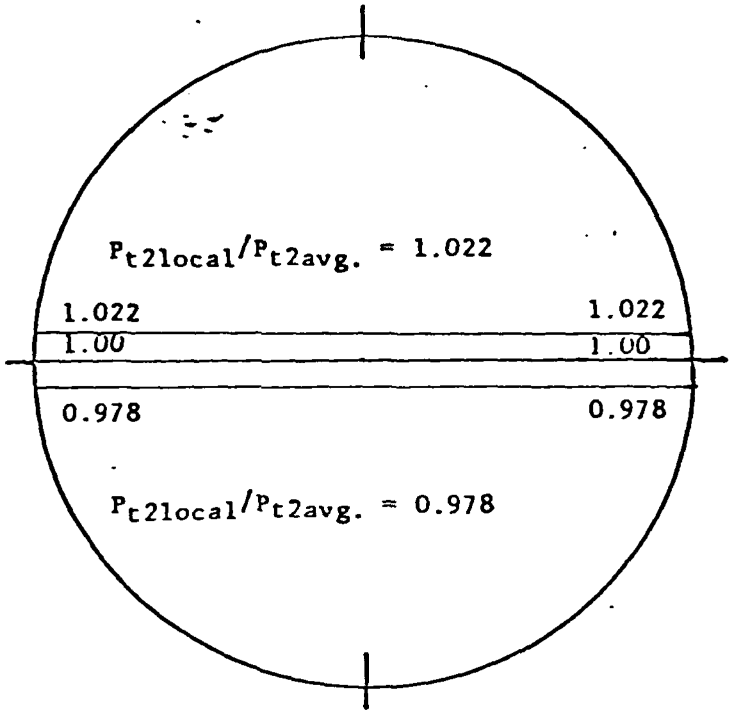


FIGURE 5. - RING PLOT



Specification Goal

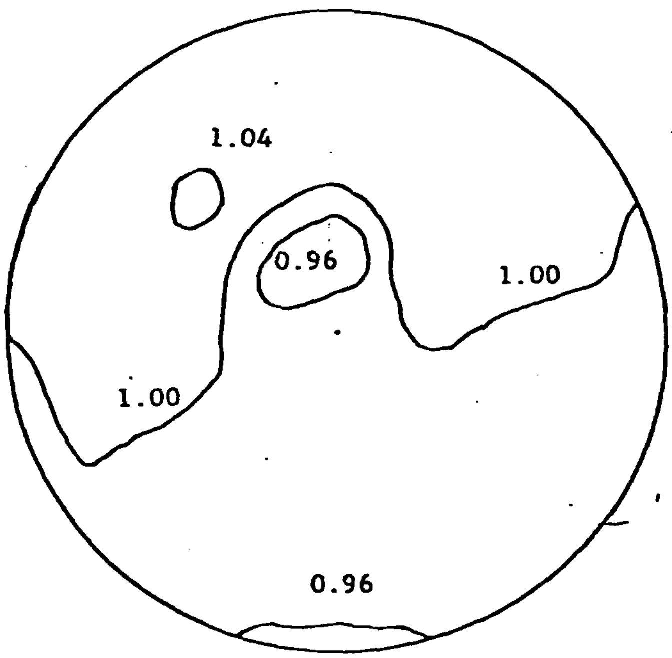


FIGURE 6. - PATTERN PRODUCED BY 180° SCREEN

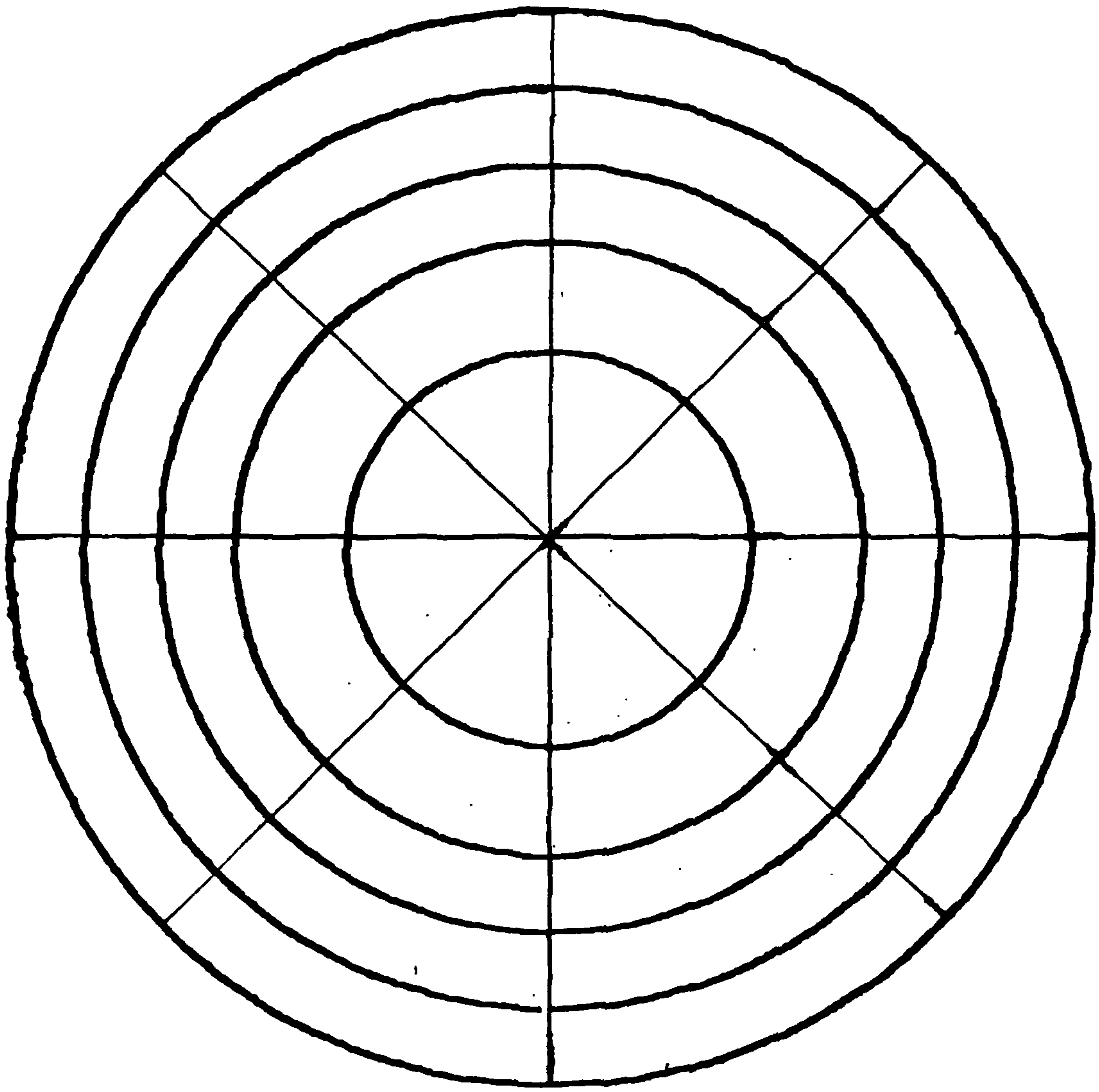


FIGURE 7. - GEOMETRIC DIVISION OF FLOW AREA

REFERENCES

1. REPORT - Overall, B. W., "A Procedure for the Design of Complex Distortion Screen Patterns for Producing Specified Steady-State Total Pressure Profiles at the Inlet of Turbine Engines," Arnold Engineering Development Center, AEDC-TR-72-10

2. AUTHORIZATION - Naval Air Systems Command Work Unit Assignment No. NAPC 519, Amendment B, of 25 August 1981

APPENDIX A

USE OF SCREEN DESIGN COMPUTER PROGRAM TITLED "SCRDES"

Encl: (1) Figures 1 through 10

The computer program titled "SCRDES" was written with various menus and questions to lead the user/screen designer through the screen design process. Enclosure (1) contains images/displays of these items as they would appear on an interactive terminal screen (figures 1-10).

The parameters which would not normally be varied are established initially in a standard file. Figure 1 shows the menu on the initial terminal display. From the menu an option is selected. When a new file is to be created, the program prompts the designer to enter the required data to complete the display shown on figure 1 following the menu. Standard data is established for airflow, temperature, certain fixed dimensions (e.g., inlet duct diameter and engine bullet nose, if appropriate) and pressure probes. After the data is entered, a new display shows the file established (figure 2). If a mistake is observed or a change is desired to the standard data, an index number can be entered to permit a change. When the index number is entered, the computer program prompts the screen designer to make the correction.

After the standard values are checked satisfactorily, a return to an option list permits the designer to either create a new data set of distortion data or use one already established in the computer (see figure 3). Aga , the computer leads the designer through the steps to create the distortion data file if a new data set is required. When completed, the file is dispalyed for verification or change if necessary (see figure 4).

Figure 5 provides a menu which includes an option for producing a contour plot, usually the next step in the screen design process. After selection of the contour plot option, the designer selects the extrapolation technique from another menu (figure 6) to define the contour from the probes to the inner and outer walls. Any number of isobars up to 10 may be selected. The program then displays the plot and calculates the area between each chosen contour level, such as in the figure 7 example. If desired, the plot can be rerun using any of the methods in the menu of figure 6. Figure 8 is a terminal display which lists the areas defined and the average total pressure of each.

With the areas and pressures defined, the porosities for the areas are calculated next. The designer picks a porosity for a chosen area (figure 9) and the computer calculates and displays the porosities for the other areas (figure 10). If a different set of porosities is desired, a new starting porosity can be typed and a new set will be calculated. The process is completed when the total calculated airflow agrees with the desired total airflow to the engine, as in figure 10. The designer

now has the information required to define an initial screen for test purposes. After testing, a new data set can be created using the pressures measured and comparing them to the desired set.

The capability in the program to alter individual parameters gives the designer the opportunity to evaluate changes to the design before the screen is physically modified. For example, pressures can be altered in the data set by choosing option 3 in the menu in figure 5. Also, specific areas and pressures may be changed in figure 8 to permit the designer to study the effect on calculated porosities and local airflow levels.

It is not possible to communicate with the computer to directly alter the position of a contour line (isobar). Movement of the lines can only take place as a result of a change in the file selected to produce the contour plot.

```
DEFINE FILE CONTAINING STANDARD INFORMATION

OPTIONS:  1  READ INFO FROM EXISTING STANDARD FILE
          2  CREATE A NEW STANDARD FILE
          3  EXIT PROGRAM

ENTER DESIRED OPTION: 2
ENTER FILE NAME FOR STANDARD FILE: STD
ENTER NUMBER OF RAKES, NUMBER OF RINGS: 8,5 .
ENTER INNER RADIUS, OUTER RADIUS: 0.,4.556
ENTER 5 RING RADII
2.056,2.796,3.371,3.860,4.260
ENTER  8 RAKE ANGLES
0.,45.,90.,135.,180.,225.,270.,315.,
ENTER TOTAL AIRFLOW, TOTAL TEMPERATURE (DEG F): 13.4,59.,
```

FIGURE 1. - STANDARD FILE SELECTION

```
FILE: STD                                NO. RAKES:  8    NO. RADII: 5
INDEX
 1  INNER RADIUS =  0.000
 2  RING RADII:
      1      2      3      4      5
    2.056  2.796  3.371  3.860  4.260
 3  OUTER RADIUS =  4.556
 4  RAKE ANGLES:
        1      2      3      4      5      6      7      8
       0.0   45.0   90.0  135.0  180.0  225.0  270.0  315.0

 5  TOTAL AIRFLOW =  13.400
 6  TOTAL TEMPERATURE (DEG F) =  59.000

ENTER INDEX
```

FIGURE 2. - STANDARD FILE FORMAT

```
CREATE A NEW DATA SET

OPTIONS:  1  COPY DATA FROM AN EXISTING DATA SET
          2  ENTER VALUES VIA KEYBORAD
          3  RETURN

ENTER DESIRED OPTION: 2
ENTER FILE NAME FOR DATA SET: NEW
ENTER  8 VALUES FOR RING # 1
12.,12.,12.,11.,12.,12.,12.,12.,
ENTER  8 VALUES FOR RING # 2
11.,11.,10.,10.,10.,10.,10.,10.,
ENTER  8 VALUES FOR RING # 3
10.,11.,11.,11.,10.,10.,9.,9.,
ENTER  8 VALUES FOR RING # 4
8.,8.,8.,8.,11.,11.,11.,11.,
ENTER  8 VALUES FOR RING # 5
7.5,8.,8.,8.,12.,12.,12.,12.,
DO YOU WANT PROGRAM TO AUTOMATICALLY FILL INNER RADIUS  DATA?: Y
DO YOU WANT PROGRAM TO AUTOMATICALLY FILL OUTER RADIUS  DATA?: Y
```

FIGURE 3. - DATA SET SELECTION

```
FILE: NEW                                        AVERAGE PRESSURE:   10.337
                                           RAKES:
               1        2        3        4        5        6        7        8
RADII:I -1.0000  -1.0000  -1.0000  -1.0000  -1.0000  -1.0000  -1.0000  -1.0000

      1  12.000   12.000   12.000   11.000   12.000   12.000   12.000   12.000
      2  11.000   11.000   10.000   10.000   10.000   10.000   10.000   10.000
      3  10.000   11.000   11.000   11.000   10.000   10.000   9.0000   9.0000
      4  8.0000   8.0000   8.0000   8.0000   11.000   11.000   11.000   11.000
      5  7.5000   8.0000   8.0000   8.0000   12.000   12.000   12.000   12.000

      0 -2.0000  -2.0000  -2.0000  -2.0000  -2.0000  -2.0000  -2.0000  -2.0000
ENTER RADII INDEX, RAKE INDEX, VALUE:
```

FIGURE 4. - DATA FILE FORMAT

```
OPTIONS:  1  MODIFY STANDARD VALUES
          2  CREATE NEW DATA SET
          3  MODIFY EXISTING DATA SET
          4  CONTOUR PLOT / SCREEN DESIGN
          5  RING PLOT
          6  EXIT

ENTER DESIRED OPTION: 4
ENTER FILE NAME FOR EXISTING DATA SET: QT5
```

FIGURE 5. - OPTION LIST

```
CHOOSE METHOD TO FILL BOUNDARY CONDITIONS
ENTER
    M - MINIMUM VALUE OF ALL PROBES
    V - VALUE OF NEAREST PROBE
    L - LINEAR FIT VALUE OF TWO CLOSEST PROBES ON RAKE
    R - LINEAR FIT - VALUE RESTRICTED TO MIN AND MAX RANGE
    S - SECOND DEGREE FIT OF 3 CLOSEST PROBES
    C - CONSTANT MULTIPLIED BY THE CLOSEST PROBE
S
PLOT RAKES WITH PROBE LOCATIONS? (YES OR NO) : Y
ACTUAL DATA MINIMUM:  7.50000     MAXIMUM:  12.0000
EXPAND DATA MINIMUM:  7.50000     MAXIMUM:  25.0392
SUGGESTED  3 CONTOURS AT THE FOLLOWING LEVELS:
   8.00  10.00  12.00
ARE CONTOUR LEVELS ACCEPTABLE? (YES OR NO) : Y
```

FIGURE 6. - CONTOUR PLOT INTERPOLATION SELECTION

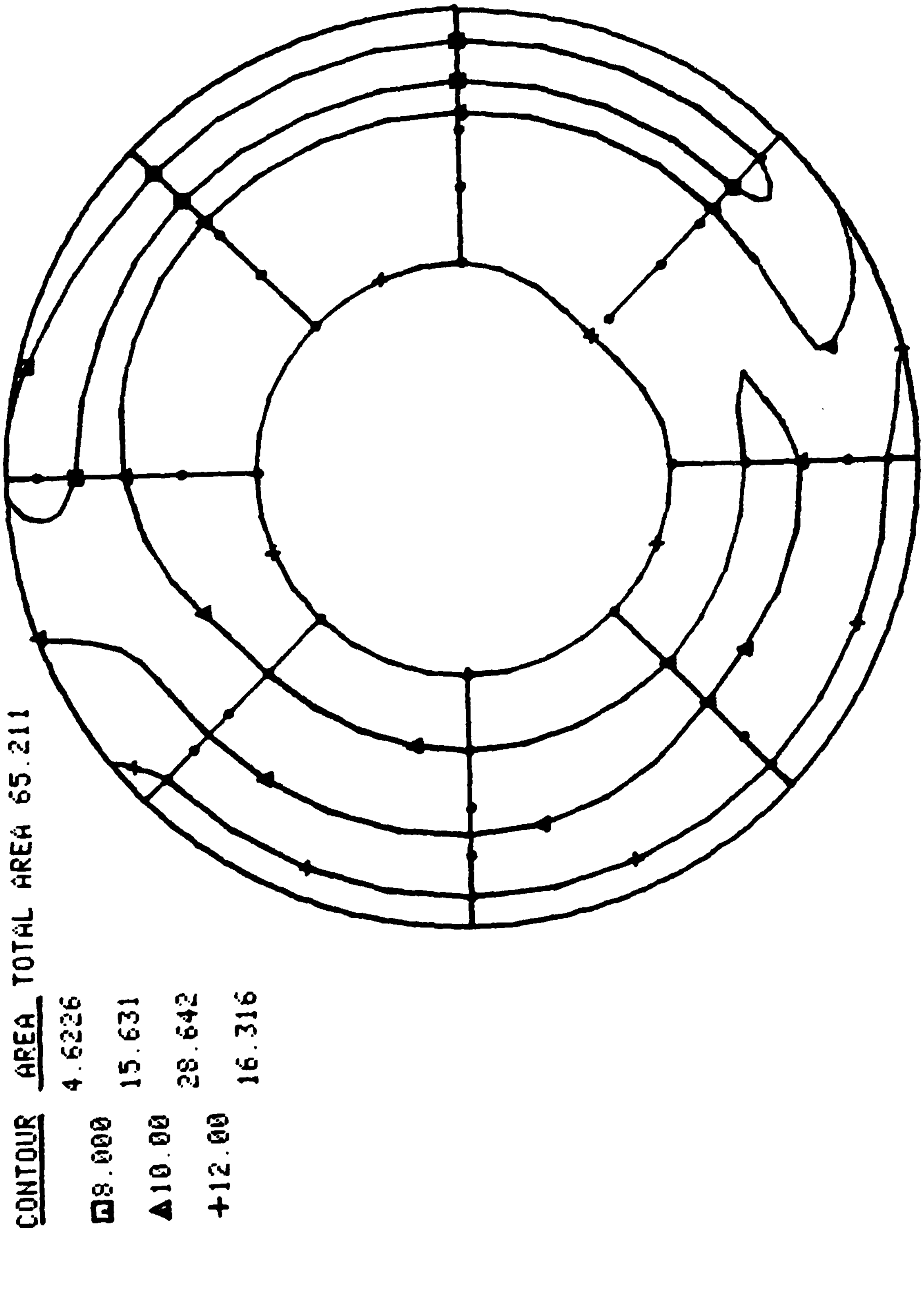


FIGURE 7. - TYPICAL CONTOUR PLOT

INDEX	CONTOUR	AREA	AVG PRESSURE
1		4.62	7.500
	8.00		
2		15.63	8.222
	10.00		
3		28.64	10.526
	12.00		
4		16.32	12.000

ENTER INDEX TO CHANGE (0 FOR NO CHANGES):

FIGURE 8. - AREAS AND PRESSURES DERIVED FROM CONTOUR PLOTS

```
TO ACHIEVE DESIGN AIRFLOW FOR A SELECTED AREA,
REQUIRES A POROSITY INPUT WHICH NORMALLY WILL BE
THE POROSITY OF THE BASE GRATE SCREEN THAT GIVES
THE LEAST OBSTRUCTION TO AIRFLOW.
HENCE IT WILL BE THE AREA WITH THE HIGHEST TOTAL PRESSURE.

WHEN THE TOTAL PRESSURE HAS BEEN ESTABLISHED, POROSITIES
FOR THE REMAINING AREAS ARE CALCULATED TO GIVE THE NEEDED
AIRFLOW FOR EACH RESPECTIVE AREA.


 ENTER AREA ZONE: 4
 4.5485821      = THE AIRFLOW AT STATIC=  6.9409990
INPUT POROSITY: .95
```

FIGURE 9. - SELECTION OF POROSITY AND ZONE

```
ZONE:  1
    AREA=  4.6225777
    AIRFLOW= 0.44190419
    LOCAL TOT PRESS=  7.5000000
    POROSITY= 0.32526216
ZONE:  2
    AREA=  15.630939
    AIRFLOW=  2.2415226
    LOCAL TOT PRESS=  8.2222223
    POROSITY= 0.48835275
ZONE:  3
    AREA=  28.641535
    AIRFLOW=  6.7729206
    LOCAL TOT PRESS=  10.526316
    POROSITY= 0.80556077
ZONE:  4   (POROSITY INPUT)
    AREA=  16.315565
    AIRFLOW=  4.5485821
    LOCAL TOT PRESS=  12.000000
    POROSITY= 0.94999999

STATIC PRESSURE=  6.9409990
UPSTREAM TOTAL PRESS=  12.591128
CALC TOTAL AIRFLOW=  14.004930
DESIGN TOTAL AIRFLOW=  14.000000


DO POROSITY CALCS AGAIN, YES OR NO
(IF "NO" IS ENTERED,PROGRAM RETURNS
TO BASIC OPTIONS):
```

FIGURE 10. - SUMMATION OF POROSITIES AND AIRFLOWS

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